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Published in:
Developmental Medicine and Child Neurology

DOI:
10.1017/S0012162205001544

Publication date:
2005

General movements in early infancy predict neuromotor development at 9 to 12 years of age

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Assessment of the quality of general movements (GMs) in early infancy is a powerful instrument to predict cerebral palsy (CP). The aim of the present study is to explore the value of GM assessment in predicting minor neurological dysfunction (MND) at 9 to 12 years of age. Two groups of infants were studied prospectively: 28 low-risk full-term infants (11 females, 17 males) and 24 high-risk infants, mostly born preterm (<37 weeks; 11 females, 13 males). In each group the quality of GMs (normal or abnormal) was assessed during two developmental periods: the age at which 'writhing' GMs occur (36 weeks' postmenstrual age to 7 weeks' postterm) and the age at which 'fidgety' GMs occur (8 to 17 weeks' postterm). Eight of 24 high-risk infants were diagnosed as having CP at 4 to 9 years of age. The remaining 44 children were followed-up at 9 to 12 years. In children without CP, quality of GMs at 'fidgety age' was related to neurological condition (normal, simple MND, complex MND) at follow-up (rbo=0.46, p<0.01). Abnormal GMs at 'fidgety-GM age' showed a specific relationship to the development of coordination problems (χ^2=6.1, p=0.01) and fine manipulative disability (Fisher, p<0.05) at 9 to 12 years. This finding supports the notion that the quality of GMs may provide information on the integrity of complex supraspinal circuitries.

See end of paper for list of abbreviations.

The number of survivors of neonatal intensive care continues to increase. These children are at high-risk for major neurodevelopmental impairments and minor developmental disorders, such as learning and behavioural problems and clumsy motor behaviour (Bhutta et al. 2002). The latter problems show a close relation to the child's neurological condition, i.e. the presence of minor neurological dysfunction (MND; Hadders-Algra 2002).

MND can be detected with the help of a standardized, age-specific neurological examination (Touwen 1979). Two basic forms of MND have been distinguished: simple and complex MND (Hadders-Algra 2002). The criteria for the two forms of MND depend on the child's age (Hadders-Algra 2002, 2003). Simple MND occurs relatively frequently and its most probable sources of origin are genetic predisposition and stress during pre- or perinatal life, such as stress related to intrauterine growth retardation, preterm entry into the extrauterine world, or mild forms of asphyxia. Simple MND might reflect the lower tail of the normal distribution of non-pathological brain function.

Complex MND is strongly related to perinatal adversities, suggesting that it might be attributed to a lesion of the brain at early age. It might be considered as a borderline form of CP (Hadders-Algra 2003). Complex MND shows a clear association with behavioural problems, specific learning disorders, and developmental coordination disorder (Hadders-Algra 2002, 2003).

During early infancy it is difficult to predict which children are at risk for the development of MND, in particular complex MND (Hadders-Algra and Groothuis 1999; Hadders-Algra et al. 2004). The relatively new assessment of the quality of general movements (GMs) during early postnatal life might assist with prediction. The assessment of GMs is a Gestalt evaluation of movement complexity, variation, and fluency (Prechtl 1990, Hadders-Algra 2004). GMs are present from early fetal life and disappear at the age at which goal-directed motor behaviour emerges at 3–4 months' postterm. Changes in movement quality reliably reflect the condition of the brain (Hadders-Algra 2004). Normal GM development is characterized by two transitions during which the form of GMs subtly changes. The transitions occur at 36–38 weeks' postmenstrual age (PMA) and 6–8 weeks' postterm. During the latter transition GMs with a 'writhing character' change into GMs with a 'fidgety character'. Fidgety GMs consist of a continuous stream of tiny, elegant movements occurring irregularly all over the body (Hadders-Algra 2004). The quality of GMs has especially predictive value during the fidgety-GM age at 2–4 months' postterm.

Recently, four different qualities of GMs have been defined: two forms of normal GMs (normal-optimal and normal-suboptimal) and two forms of abnormal GMs (mildly abnormal and definitely abnormal; see Table I; Hadders-Algra et al. 2004). The presence of definitely abnormal GMs at fidgety-GM age is known to be associated with a high risk of the development of CP (Prechtl et al. 1997, Hadders-Algra and Groothuis 1999). Mildly abnormal GMs at fidgety-GM age are associated with an increased risk for the development of MND, ADHD, and aggressive behaviour at early school-age (Hadders-Algra and Groothuis 1999).

It is unknown whether the quality of GMs (e.g. normal-suboptimal) is related to neuromotor condition (e.g. simple MND) at the second half of primary school-age (9–12 years), an age at which complex motor functions have achieved

virtually full expression (Lunsing et al. 1992). The main objective of the present explorative study was to assess whether quality of GMs during early infancy in children without CP is related to the presence, severity, and type of MND at 9 to 12 years. The value of GM assessment for the prediction of MND at 9 to 12 years will be compared with that of the traditional neurological assessment during early infancy (Touwen 1976).

In addition to the main question of whether GMs predict neuromotor condition, four additional issues were addressed which deal with predictive value of GM quality in children with and without CP: (1) Does a refined classification system using a 10-point Likert-score enhance the accuracy of predicting outcome? Users of GM assessment have indicated appreciation of the 10-point scoring system (e.g. Hornstra et al. 2003) but no data are available on its predictive validity. (2) Does an occasionally occurring 'cramped-synchronized' GM have predictive value for the development of CP or complex MND? During the pathological cramped-synchronized GM the infant suddenly contracts and relaxes all limb and trunk muscles simultaneously. Ferrari et al. (2002) demonstrated that in children with CP the number of weeks during which the infant persistently showed cramped-synchronized GMs was related to severity of disability. (3) Does a difference in movement quality between arms and legs have prognostic significance? (4) Does the type of non-fluency of motility, i.e. whether movements are abrupt, stiff, or vary between abrupt and stiff, have prognostic significance?

The latter two additional issues originated from clinical experience.

Method

PARTICIPANTS

The study group consisted of 52 children born in the University Medical Center (UMC), Groningen from 1988 to 1993. All children participated in past EMG-studies on the development of normal and abnormal GMs (Hadders-Algra et al. 1997). Twenty-four of the 52 children, born from 1991 to 1993 were admitted to the neonatal intensive care unit of the Beatrix Children's Hospital, (UMC), Groningen. They were considered to be at high risk of developmental problems, either on the basis of problems associated with preterm birth (<37wks; $n=18$) or hypoxic–ischemic encephalopathy after term birth ($n=6$). Twenty-eight children were born at term without perinatal complications from 1988 to1992. They had been recruited at the obstetric department of the UMC, Groningen and they were considered to be at low risk for developmental problems. See Table II for clinical data. All children were re-examined neurologically between 4 and 9 years of age (Hadders-Algra and Groothuis 1999, Hadders-Algra et al. 2004).

Table I: Classification of quality of general movements (GMs; Hadders-Algra et al. 2004)

Classification of GMs	*Complexity*	*Variation*	*Fluency*
Normal-optimal	+++	+++	+
Normal-suboptimal	++	++	–
Mildly abnormal	+	+	–
Definitely abnormal	–	–	–

Complexity and variation: +++, abundantly present; ++, sufficiently present; +, present but insufficiently; –, virtually absent or absent. Fluency (least important aspect of GM assessment): +, present; –, absent.

GM ASSESSMENT

Spontaneous motility in supine position was video-recorded multiple times during the first postnatal months. Each recording lasted for at least 10 minutes. A total of 208 videotapes of all 52 children were assessed and categorized according to GM ages: 21 during the preterm-GM age (before 38 weeks' PMA), 86 during the writhing-GM age (38–47 weeks' PMA), and 101 during fidgety-GM age (8–17 weeks' postterm). Only movements during an awake, active, non-crying state were analyzed to prevent a confounding effect of behavioural state (Hadders-Algra et al. 1993).

On the basis of the video-recordings, quality of GMs was evaluated by two assessors: one being completely blind to the clinical data of the infants (SEG), the other knowing the high- or low-risk status of the infant (MHA). All video-recordings were scored by each assessor independently. If case discrepancies occurred, videos were reassessed and discussed until consensus was reached. GMs were classified into four quality types: normal-optimal GMs (abundant variation and complexity, fluent), normal-suboptimal GMs (sufficiently variable and complex, non-fluent), mildly abnormal GMs (insufficiently variable and complex, non-fluent), and definitely abnormal GMs (variation and complexity virtually absent, non-fluent; Table I).

A refined quality assessment was used which consisted of a Likert (10-point) score, with higher scores denoting better movement qualities. Scores of normal-optimal GMs ranged from 8–10, those of normal-suboptimal GMs from 6–7, those of mildly abnormal GMs from 4–5, and those of definitely abnormal GMs from 1–3. In addition, the following three features of GMs were assessed: (1) the presence of a cramped-synchronized pattern; (2) the presence of a discrepancy in quality of movements of the arms and legs; and (3) the type of non-fluent movements, i.e. whether movements were predominantly jerky, stiff, or whether movements consisted of a mix of jerky and stiff movements. Interobserver agreement of the classification into the four main categories is very good (Cohen's kappa (κ)=0.81; Hadders-Algra et al. 2004).

Interobserver agreement on three of the four additional features was determined on the basis of a random sample of 25 videos: discrepancy in quality of movements of arms and legs, $\kappa=0.71$; type of non-fluent movements, $\kappa=0.69$; Likert 10-point score, Spearman's *rho*=0.90. Interobserver agreement for the infrequently occurring cramped-synchronized movements was determined on the basis of a random sample of 50 videos. This resulted in a kappa value of $\kappa=0.70$. This means that all details of interest in this GM study could be assessed reliably. In case of disagreement on specific characteristics of GMs, movement quality was discussed until consensus was reached.

Previously this investigative group reported that movement quality is relatively stable within a GM phase (preterm, writhing, and fidgety; Hadders-Algra et al. 2004). This allowed for a data-reduction procedure, i.e. to summarize GM characteristics per GM phase. This meant that the most prevalent score was taken for the classification into the four main categories (Table 1), the discrepancy in movement quality between arms and legs and the type of non-fluent motor behaviour i.e. whether movements are abrupt, stiff, or vary between abrupt

and stiff. If two scores were equally prevalent, the best score was taken as representative of that period. If an infant showed in a GM phase during one recording a worse quality of movements in the arms than in the legs, but during another recording a worse quality of movements in the legs than in the arms, outcome was classified as 'no difference in quality between arms and legs'. If an infant in a GM phase during one recording showed abrupt movements and during another stiff movements, movement non-fluency was classified as being 'mixed' during that period.

The cramped-synchronized pattern was considered to be present during a GM phase when it was observed during at least one recording. The variation in the 10-point score within a GM phase did not exceed two points. If a two-point difference was present, the mean value was considered to represent the GM score. In the case of a one-point difference, the most frequently occurring value summarized the score during that period. If there was an equal prevalence of two scores the better of the two was taken. For the resulting GM parameters – occasional occurrence of cramped-synchronized GMs, discrepancies in quality of arm and leg motility, and types of non-fluent motor behaviour – occurrence rates per single recordings per GM phase were calculated.

NEUROLOGICAL ASSESSMENT DURING INFANCY

At the time of each video-recording for GM assessment of infants there was also a standardized neurological examination (techniques of Prechtl 1977 with age-specific adaptations of the norms according to Touwen 1976). Neurological findings were summarized as normal, mildly abnormal or definitely abnormal. 'Definitely abnormal' denoted the presence of a full-blown neurological syndrome, such as hemisyndrome, a hyperexcitability syndrome, or a clear hypo-or hypertonia. 'Mildly abnormal' neurological findings indicated the presence of only a few signs of a full syndrome, such as mild dysfunction in tone regulation, or mild but consistent asymmetry in neuromotor behaviour.

To compare the predictive value of GM assessment and that of the neurological examination, neurological assessments were summarized according to GM phase. This meant that the most prevalent condition within a period was regarded as the representative condition. If two conditions were equally prevalent, the better neurological condition was taken as representative for that period.

NEUROLOGICAL ASSESSMENT AT FOLLOW-UP

From the total study group of 52 children, 44 children were invited to participate in the follow-up at age 9–12 years. The eight children who were not invited for reassessment belonged to the high-risk group and had been diagnosed as having CP at follow-up between 4 and 9 years, an age at which the diagnosis of CP can be considered stable. Classification of CP implies the presence of a 'classical' configuration of neurological signs, such as – in cases of spastic diplegia – the combination of a stereotyped posture and motility of the legs, increased muscle tone and brisk tendon reflexes in the legs, and Babinski signs. Children with MND do not exhibit these classical combinations of signs. Data of the eight children with CP were included in parts of the present analyses. Three low-risk children were lost to follow-up due to refusal of the parents and/or children to participate. Two of these three children were considered to be neurologically normal and one as having simple MND at the previous follow-up. Thus, 41 children were reassessed at the age of 9–12 years. All parents gave informed consent and the procedures were approved by the Ethics Committee of the UMC, Groningen.

The standardized and age-specific neurological examination according to Touwen (1979) was carried out by the first author who was unaware of perinatal history or quality of GMs of the children. This assessment technique is proven to be reliable (kappa [κ] values of interobserver agreement for the various clusters: κ=0.70–0.98; Hadders-Algra and Groothuis 1999, Kakebeeke et al. 1993) and is especially designed to detect MNDs, such as mild abnormalities in muscle tone, mild coordination problems, or fine manipulative disability.

Neurological findings were summarized into functional clusters of dysfunction: mild abnormalities in posture and muscle tone, mild abnormalities in reflexes, problems in

Table II: Clinical data of study group

	Low-risk		*High-risk*			
			Term[a]		*Preterm*[b]	
	n=28[c]	*n=25*[d]	*n=6*[c]	*n=3*[d]	*n=18*[c]	*n=13*[d]
Neonatal data						
Gestational age at birth,						
Median (range)	40 (38–43)	40 (38–43)	40 (38–43)	38 (38–40)	30 (26–36)	30 (26–36)
Birthweight, g						
Mean (SD)	3467 (499)	3521 (489)	3014 (394)	2750 (241)	1438 (548)	1300 (438)
Sex, M/F	17/11	15/10	2/4	1/2	11/7	9/4
Early postnatal assessments[e]						
Median (range)						
At preterm-GM age	0	0	0	0	1 (0–3)	1 (0–3)
At writhing-GM age	2 (1–2)	2 (1–2)	3 (1–3)	2 (2–3)	2 (1–3)	2 (1–3)
At fidgety-GM age	2 (1–3)	2 (1–3)	2 (1–3)	2	2 (1–3)	2 (1–3)
Age at follow-up, mo (range)		137 (113–150)[f]		111 (107–118)		115 (108–126)

[a]Hypoxic–ischaemic encephalopathy. [b]Preterm, <37 weeks. [c]Original group (Hadders-Algra et al. 1997); [d]Children re-assessed at 9–12 years; [e]Preterm-GM age, <38 weeks' postmenstrual age (PMA); writhing-GM age, 38–47 weeks' PMA; fidgety-GM age, 8–17 weeks' post-term. [f]Difference between low-risk and high-risk children: Student *t-test* $p<0.0001$.

coordination and balance, fine manipulative disability, choreiform dyskinesia, and, rarely, miscellaneous dysfunctions. On the basis of the neurological examination, children were classified according to condition such as neurologically normal, simple MND, or complex MND. Simple MND denoted the presence of one or two clusters of dysfunctions, and complex MND denoted the presence of more than two clusters of dysfunction (Hadders-Algra 2002, Hadders-Algra et al. 2004). At follow-up, parents filled in a standardized form on diseases and more generalized conditions of the child which occurred between discharge from the hospital in the neonatal period and follow-up. Special attention was paid to diseases which might interfere with neurological development, such as gastroenteritis with dehydration and head trauma (Hadders-Algra 2002).

STATISTICS

The non-parametric Fisher exact test and χ^2 were used to evaluate the relationships between dichotomized parameters of GM quality or infant neurological condition and neurological outcome at 9–12 years. To assess the relationships between GM-classification and the 10-point score on GM-quality on the one hand and neurological outcome on the other hand, Spearman's rank correlations were used. Throughout the analyses $p<0.05$ was considered to be statistically significant (two-tailed).

Results

GM CLASSIFICATION AND NEUROLOGICAL OUTCOME AT 9–12 YEARS

At 9–12 years, 16 children were classified as neurologically normal, 22 as simple MND, and three as complex MND. The three children with complex MND were members of the high-risk group and were born preterm. Simple MND occurred in 10 of the 21 children of the low-risk group and in 12 of the 23 children of the high-risk group without CP. The most frequently observed clusters of dysfunction were mild abnormalities in coordination problems (14 of 41), posture and muscle tone (13 of 41), and fine manipulative disability (8 of 41). The presence of MND could not be explained by diseases which had occurred in the interval between neonatal discharge from the hospital and follow-up.

The focus of this report is on GM quality at writhing-GM and fidgety-GM ages, as this information was available for all infants. The relationships between GM classification at writhing-GM and fidgety-GM ages and neurological condition at follow-up

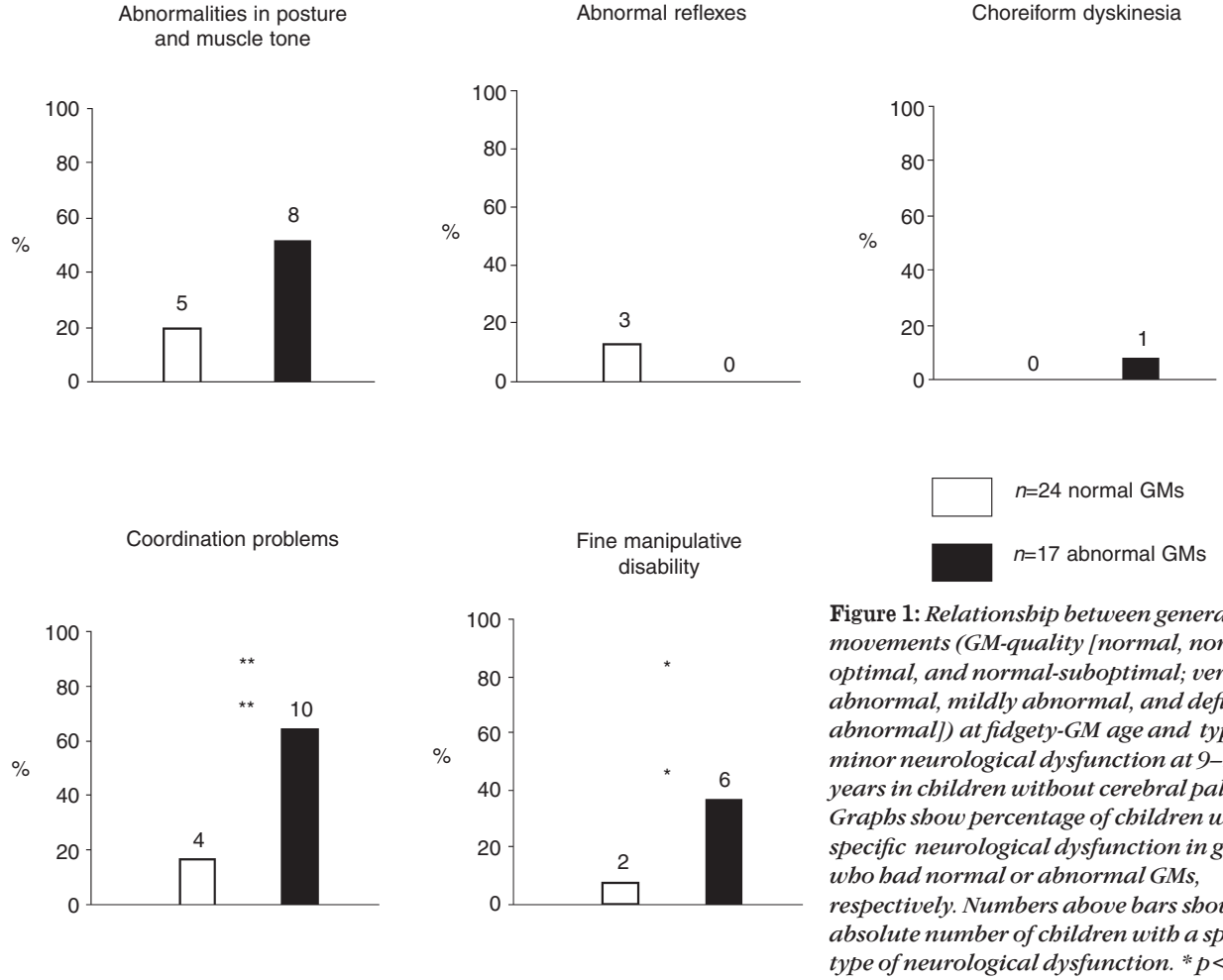

Figure 1: *Relationship between general movements (GM-quality [normal, normal-optimal, and normal-suboptimal; versus abnormal, mildly abnormal, and definitely abnormal]) at fidgety-GM age and type of minor neurological dysfunction at 9–12 years in children without cerebral palsy. Graphs show percentage of children with specific neurological dysfunction in group who had normal or abnormal GMs, respectively. Numbers above bars show absolute number of children with a specific type of neurological dysfunction. * $p<0.05$, ** $p<0.01$.*

are presented in Table IIIa and IIIb. The presence of definitely abnormal GMs at writhing-GM and fidgety-GM ages was related to the development of complex MND (Fisher: writhing-GM age $p=0.02$; fidgety-GM age $p=0.004$).

Classification of GMs into four categories at writhing-GM age was not significantly related to neurological condition (normal, simple MND, complex MND) at follow-up (rho=0.29, $p=0.06$; Table IIIa). However, GM-classification at fidgety-GM age was ($rho=0.46$, $p<0.01$; Table IIIb). Presence of mildly or definitely abnormal GMs in early life was not related to minor dysfunction in posture and muscle tone or to the presence of abnormal reflexes at follow-up (Fig. 1). Similarly, the presence of abnormal GMs at writhing-GM age was not significantly related to the development of coordination problems and fine manipulative disability at 9–12 years. However, the presence of abnormal GMs at fidgety-GM age did show a significant relationship with the presence of coordination problems ($\chi^2=6.1$, $p=0.01$) and fine manipulative disability at follow-up (Fisher, $p<0.05$; Fig. 1).

NEUROLOGICAL CONDITION IN INFANCY AND NEUROLOGICAL CONDITION AT 9–12 YEARS

The traditional neurological examination revealed that at writhing-GM age three infants had a definitely abnormal condition, five had a mildly abnormal condition, and the other infants were neurologically normal. At fidgety-GM age none of the infants had been classified as definitely abnormal, seven were classified as mildly abnormal, and the other infants were neurologically normal. The presence of a mildly or definitely abnormal neurological condition during these two GM periods was not related to the development of complex MND, minor dysfunction in posture and muscle tone, the presence of abnormal reflexes at follow-up, or coordination problems. However, the presence of a mildly or definitely abnormal neurological condition during writhing- and fidgety-GM ages was related to the development of fine manipulative disability (Fisher, writhing-GM age: $p=0.03$; fidgety-GM age: $p=0.02$).

SPECIFICS OF GMS AND NEUROLOGICAL OUTCOME

Likert 10-point score and outcome

Given that quality of GM classification and neurological condition at follow-up were related, particularly at fidgety-GM age, it is not surprising that the 10-point score of the quality of GMs also was related to neurological condition at follow-up (all children: writhing-GM age $rho=0.58$, $p<0.0001$, fidgety-GM age $rho=0.72$, $p<0.0001$; children without CP: writhing-GM age $rho=0.27$, $p=0.09$, fidgety-GM age $rho=0.53$, $p<0.0001$).

The addition of the 10-point score to the classification in the four basic GM categories did not improve the predictive power of GM assessment (see Table IV). For instance, developmental outcome in the twelve children presenting at fidgety-GM age with mildly abnormal GM and a score of 5 (higher mildly abnormal GM score) was heterogeneous: three children were neurologically normal, seven exhibited simple MND, one showed complex MND, and one had a mild spastic hemiplegia. Outcome in the four children showing mildly

Table IIIa: Relationship between general movements (GMs) at writhing-age and neurological outcome at 9–12 years

Quality of GMs	*Neurological outcome*			
	Normal	*Simple MND*	*Complex MND*	*Total*
	n	*n*	*n*	*n*
Normal-optimal	0	2	0	2
Normal-suboptimal	11	10	0	21
Mildly abnormal	5	8	1	14
Definitely abnormal	0	2	2	4
Total	16	22	3	41

MND, minor neurological dysfunction.

Table IIIb: Relationship between general movements (GMs) at fidgety age and neurological outcome at 9–12 years

Quality of GMs	*Neurological outcome*			
	Normal	*Simple MND*	*Complex MND*	*Total*
	n	*n*	*n*	*n*
Normal-optimal	1	1	0	2
Normal-suboptimal	12	10	0	22
Mildly abnormal	3	11	1	15
Definitely abnormal	0	0	2	2
Total	16	22	3	41

MND, minor neurological dysfunction.

Table IV: Relationship between Likert-score of quality of general movements (GMs) at fidgety age and neurological outcome

GM classification		*Neurological outcome*				
Class	*10-point score*	*Normal*	*Simple MND*	*Complex MND*	*Cerebral palsy*	*Total*
DA	2	0	0	0	3	3
DA	3	0	0	2	4	6
MA	4	0	4	0	0	4
MA	5	3	7	1	1	12
SO	6	5	8	0	0	13
SO	7	7	2	0	0	9
NO	8	1	1	0	0	2
Total		16	22	3	8	49

MND, minor neurological dysfunction; Class, GM classification: DA, definitely abnormal; MA, mildly abnormal; SO, normal-suboptimal; NO, normal-optimal. 10-point scores range from 1 to 10, but in present study only values ranging from 2 to 8 were present.

abnormal GMs with a score of 4 (lower mildly abnormal GM score) was not worse, as all showed simple MND at follow-up (Table IV).

Occasionally occurring cramped-synchronized GMs and outcome

Cramped-synchronized GMs were only observed in infants with mildly or definitely abnormal GMs. The pathological movement pattern was observed during eight of 73 recordings classified as mildly abnormal (11%) and in 21 out of 43 recordings classified as definitely abnormal (49%). Seven of the nine children who showed cramped-synchronized GMs at least during one recording at the writhing-GM age developed CP; the other two children developed complex MND. Four infants exhibited cramped-synchronized GMs at least once at fidgety-GM age: two developed CP, one complex MND, and one simple MND. The presence of cramped-synchronized GMs at writhing-GM age was significantly related to the development of CP (Fisher, $p=0.001$) and complex MND (Fisher, $p=0.004$). The presence of cramped-synchronized GMs at fidgety-GM age did not show a statistically significant relationship with the development of CP or complex MND.

Discrepancy in movement quality between arms and legs and outcome

In approximately a quarter of the video recordings a difference in movement quality of arms and legs was noticed (57 of 208, 27%). A poorer movement quality in the legs than the arms was more frequently observed (49 of 208, 24%) than worse quality in the arms (8 of 208, 4%). Movements during which the quality of leg movements was worse than that of the arms were predominantly seen in recordings at preterm-GM and writhing-GM ages (in 43% and 33% respectively). At fidgety-GM age such a discrepancy in movement quality to the disadvantage of the legs was observed in only 12% of the recordings. An inhomogeneous distribution of GM quality concerning arm or leg movements occurred more often during abnormal GMs (mildly abnormal: 35%; definitely abnormal: 37%) than during normal GMs (normal-optimal: 0%; normal-suboptimal: 18%). A discrepancy in movement quality of arms and legs was not related to the development of CP. In children without CP, the quality of leg movements was worse than that of the arms at writhing-GM age and was related to the development of complex MND (Fisher, $p=0.008$). At fidgety-GM age a similar relationship with neurological outcome was absent (see Table V).

Type of non-fluency of GMs and outcome

GMs were often non-fluent. Predominantly jerky movements occurred at preterm-GM and writhing-GM ages in 29 to 40% of recordings, and at fidgety-GM age in 69 of 101 (68%) recordings. Predominantly stiff movements were observed in 24% of recordings at preterm-GM and writhing-GM age and in 8 of 101 (8%) recordings at fidgety-GM age. Jerky movements were significantly higher in recordings with normal-suboptimal GMs (63 of 85 recordings) than in recordings with abnormal GMs (45 of 116; $\chi^2=24.6$, $p<0.001$). Stiff movements occurred

Table V: Presence of discrepancy in movement quality of arms and legs and neurological outcome

Discrepancy	*Neurological outcome*				
	Normal	*Simple MND*	*Complex MND*	*CP*	*Total*
	n	*n*	*n*	*n*	*n*
At writhing-GM age					
No discrepancy/or arms worse quality[a]	14	18	0	5	37
Legs worse quality	2	4	3	3	12
At fidgety-GM age					
No discrepancy/or arms worse quality[a]	16	21	2	7	46
Legs worse quality	0	1	1	1	3

MND, minor neurological dysfunction; CP, cerebral palsy. [a]Very few infants showed general movements (GMs) during which quality of arm movements was worse than legs. These data were pooled with 'no discrepancy' data.

Table VI: Type of non-fluent general movements (GMs) and neurological outcome

Type of non-fluency	*Neurological outcome*				
	Normal	*Simple MND*	*Complex MND*	*CP*	*Total*
	n	*n*	*n*	*n*	*n*
At writhing-GM age					
Jerky and stiff	7	9	1	4	21
Predominantly jerky	7	8	0	2	17
Predominantly stiff	2	3	2	2	9
At fidgety-GM age					
Jerky and stiff	4	7	2	2	15
Predominantly jerky	11	14	0	4	29
Predominantly stiff	0	0	1	2	3

MND, minor neurological dysfunction; CP, cerebral palsy.

more often in recordings with abnormal GMs (28 of 116) than in recordings with normal-suboptimal GMs (6 of 85; $\chi^2=10.2$, $p=0.001$). The presence nor the type of non-fluency of GMs was related to neurological condition at follow-up. Nevertheless, the rare occurrence of predominantly stiff movements at fidgety-GM age ($n=3$) was associated with an unfavourable outcome (see Table VI).

Discussion

The present study indicated that, also in children without CP, GM quality at fidgety-GM age is related to the severity and type of neurological outcome at 9–12 years of age.

Before addressing the clinical and pathophysiological aspects of the study, there are several methodological points to raise. The study group was relatively small and consisted of two groups of selected infants (high-risk and low-risk). It is a common procedure to use such selected groups to evaluate the potential predictive value of an early assessment technique. Yet, the results of the present study cannot be extrapolated directly to the general population. The high prevalence of simple MND in the low-risk group (10 of 21; 46%) indeed suggests that we dealt with a negative selection of the general population where the estimated prevalence of simple MND is 15% (Hadders-Algra 2002). Negative sampling might be attributed to all low-risk infants having been delivered and recruited at UCM, Groningen which, in the Netherlands with a high rate of home deliveries, might be an indication of non-optimal obstetrical conditions.

Another methodological issue which deserves attention is that the low-risk children were significantly older at follow-up than the high-risk children (Table II). The prevalence of MND before puberty is known to increase with increasing age (Hadders-Algra 2002). This means that in the younger high-risk group the signs of MND were relatively under-represented compared with those in the older low-risk group. This might have occluded some differences between low- and high-risk groups, and between groups with normal, mildly abnormal, and definitely abnormal GMs. Nevertheless, clear differences in neurological outcome in the various groups were found.

The present study showed that GM quality at fidgety-GM age is not only a valuable instrument to predict CP, but is also related to severity and type of MND at the second half of primary school age. It also showed that abnormal GMs were more strongly related to the development of complex MND than abnormal findings from the traditional infant neurological examination (Cioni et al. 1997). This does not mean that the assessment of GMs should replace the infant neurological examination, as both types of assessment can be considered as complementary neurological tools (Hadders-Algra et al. 2004).

The finding that fine manipulative disability and coordination problems were related to abnormal GMs at fidgety-GM age, indicates that the quality of GMs may provide information on the integrity of complex supraspinal circuitries, such as cortico-striato-thalamo-cortical and cerebello-thalamo-cortical circuitries. These types of MND are related to specific learning disorders and behavioural problems, such as attention disorder (Soorani-Lunsing et al. 1993, Hadders-Algra 2002, Batstra et al. 2003).

The present study also demonstrated that even an occasionally occurring cramped-synchronized GM, especially during the writhing-GM period, decreases the chance of a favourable neurological outcome. This finding, which emphasizes the pathological nature of the cramped-synchronized pattern (Hadders-Algra 1993), indicates that during GM assessment, attention should be paid to the occurrence of this movement pattern.

It was found that a refinement of GM assessment consisting of a 10-point Likert score to estimate the amount of variability and complexity of GMs, did not enhance the predictive power of GM assessment. This finding emphasizes the global nature of GM assessment (Prechtl 1990). Two additional findings also support the notion that GM assessment is essentially an evaluation of the infant's motor repertoire and not of the infant's capacity to produce fluent movements (Hadders-Algra et al. 2004). First, the finding that movements with a reduction of movement complexity and variability in only a part of the body, such as the legs, are related to the development of complex MND; and second, the finding that many infants show non-fluent GMs and that presence of non-fluent movements was not related to neurological outcome.

Conclusion

The present study suggests that the quality of GMs, and in particular the complexity and variation of these movements, at the age of 2–4 months' postterm cannot only be used as an instrument to predict CP, but also can be applied as a tool to detect at an early age children who are likely to have an MND later, in particular fine manipulative disability and coordination problems. Further studies in larger populations are needed to determine the precise value of GM assessment for the early detection of clinically relevant forms of MND.

DOI: DOI: 10.1017/S0012162205001544

Accepted for publication 15th December 2004.

Acknowledgements

We thank Ms Lidy Kingma-Balkema for her skilful technical assistance.

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List of abbreviations

GM	General movements
MND	Minor neurological dysfunction
PMA	Postmenstrual age